Claims

1. A wafer measurement system for use within a wafer process tool, comprising:

a wafer handler associated with the wafer process tool for feeding wafers between a cassette and any one or more of a plurality of stations of the wafer process tool;

a wafer measurement station forming one of the stations of the wafer process tool, the measurement station having a wafer support in communication with the wafer handler, the measurement station also having therein an optical measurement system forming a scatterometry instrument that is moveable by a stage to specified locations over the wafer support, the optical measurement system optically coupled to a light source to direct a light beam as a spot onto patterned features of a wafer surface on the wafer support, wherein the light beam is characterized by a spot size that is larger at the wafer surface than a periodicity of the patterned features, the head also having a light collector associated with a detector whereby illuminated features on the wafer yield characteristic optical signatures with independent optical parameters in the signatures including one or more of wavelength, incidence angle, and altitude and azimuthal collection angles; and

a data processor analyzing the characteristic signatures of a wafer using a scattering model for possible periodic structures on a wafer to obtain a measure of the patterned features on the wafer so that a process carried out by the wafer process tool can be analyzed.

2. The apparatus of claim 1 wherein the optical measurement system includes an objective lens imaging light from a spot on the wafer.

3. The apparatus of claim 2 wherein the optical measurement system forms a low numerical aperture (NA) system with an NA < 0.4 for optimum scatterometry.

4. The apparatus of claim 2 wherein the optical measurement system includes a pinhole aperture associated with the light collector receiving light from the wafer, with the objective lens imaging light traveling in opposite directions, the pinhole aperture maintaining a fixed optical relationship to the objective lens as it moves.

5. The apparatus of claim 2 wherein the movable optical measurement system comprises a confocal microscope-based measurement system.

6. The apparatus of claim 2 wherein the measurement system further includes an apodizer located near the objective aperture stop of the microscope-based system.

7. The apparatus of claim 2 wherein illumination and collection paths of the microscope-based system separate at an inconel plate beamsplitter.

8. The apparatus of claim 1 wherein the light beam incident on the wafer is substantially unpolarized and the optical measurement system is substantially polarization insensitive.

9. The apparatus of claim 1 wherein the wafer handler feeds wafers into the wafer measurement station with a unspecified wafer orientation relative to the optical measurement system.

10. The apparatus of claim 1 wherein the optical measurement head directs the light beam at normal incidence onto the wafer surface.

11. The apparatus of claim 1 wherein the measure of patterned features obtained by the data processor includes at least one dimension of lateral or vertical geometric structure of features on the wafer.

12. The apparatus of claim 11 wherein the measure of patterned features include line width and profile of features of the wafer.

13. The apparatus of claim 12 wherein the profile of pattern features is characterized by a feature height or depth that may be variable with lateral position across the features, the scattering model used by the data processor taking such variable feature height or depth dependence on lateral position into account.

14. The apparatus of claim 1 wherein the measure of patterned features obtained by the data processor includes any one or more of: overlay, erosion, residue, trench depth, film thickness, contact hole shape and size, open or closed state of contacts, and line edge roughness.

15. The apparatus of claim 1 wherein the measurement station includes an optical absorber positioned to one side of the wafer support to provide a reference zero reflectance measure for bright background measurement.

16. The apparatus of claim 1 further comprising an x-y stage driving the optical measurement system, the wafer support holding the wafer stationary within the wafer measurement station.

17. The apparatus of claim 1 wherein the wafer support is capable of moving a wafer in at least one dimension.

18. The apparatus of claim 17 wherein the wafer support is rotatable to any of a plurality of angular orientations (q) of wafer features relative to the measurement head without (x,y) translation of the wafer, and a linear stage drives the optical measurement system relative to a radial position (r) of the wafer.

19. The apparatus of claim 17 wherein the wafer support provides (x,y) translation of a wafer.

20. The apparatus of claim 17 wherein the wafer support is tiltable to any of a plurality of incidence angles of said beam onto said wafer surface.

21. The apparatus of claim 1 wherein the wafer support provides at least a 3-pin wafer contact.

22. The apparatus of claim 1 wherein the wafer support comprises a vacuum chuck.

23. The apparatus of claim 1 wherein the measurement station includes a window located between the measurement system and the wafer support to isolate a wafer from potential contamination by the movable optical system.

24. The apparatus of claim 23 wherein the measurement station is otherwise unsealed from the process tool environment.

25. The apparatus of claim 23 wherein the window is removable to permit cleaning and maintenance of the optical measurement system and a stage for moving the system.

26. A scatterometry instrument integrated within a wafer measurement station that forms one station of wafer process tool, the process tool having a wafer handler associated therewith feeding wafers between a cassette and one or more of a plurality of stations of the process tool, the wafer measurement station having, in addition to the spectrometry instrument, a wafer support with a capacity for locating a wafer at a measurement position, wherein the scatterometry instrument comprises:

a movable stage;

an optical measurement system mounted on said stage for movement by said stage to one or more specified locations over a wafer held by a stationary or movable wafer support in the measurement position, the measurement system being in optical communication with a light source for directing a light beam as a spot onto

patterned features of a wafer on the wafer support, wherein the light beam is characterized by a spot size that is larger at the wafer surface than a periodicity of the patterned features, the measurement system having collection optics associated with a detector for collecting and detecting light scattered from the portion of the wafer illuminated by the light beam, whereby features on the wafer yield characteristic optical signatures with independent optical parameters of the signatures including one or more of wavelength, incidence angle, and altitude and azimuthal collection angles; and

a data processor in communication with the detector, the data processor analyzing the characteristic optical signatures using a scattering model for possible periodic structures on a wafer to obtain a measure of the patterned features on the wafer such that a process carried out by the wafer process tool can be analyzed.

27. The instrument of claim 26 wherein the optical measurement system directs the light beam at normal incidence onto the wafer.

28. The instrument of claim 26 wherein the collection optics of the measurement system includes an objective lens positioned to image light scattered from a spot on the wafer.

29. The instrument of claim 28 wherein the measurement system forms a low numerical aperture (NA) optical system with NA < 0.04 for optimum scatterometry.

30. The instrument of claim 28 wherein the measurement system includes a pinhole aperture associated with the light collector receiving light from the wafer , with the objective lens imaging light traveling in opposite directions, the pinhole aperture maintaining a fixed optical relationship to the objective lens as the optical system moves.

31. The instrument of claim 26 wherein the light source is optically coupled to the optical measurement system via an optical fiber.

32. The instrument of claim 26 wherein the movable optical measurement system comprises a confocal microscope-based measurement system.

33. The instrument of claim 26 wherein the measurement system further includes an apodizer located near the objective aperture stop of the microscope-based system.

34. The instrument of claim 26 wherein illumination and collection paths of the microscope-based system separate at an inconel plate beamsplitter.

35. The instrument of claim 26 wherein the light beam incident on the wafer is substantially unpolarized and the optical measurement system is substantially polarization insensitive.

36. The instrument of claim 26 wherein the wafer handler of the process tool and the wafer support in the wafer measurement station provide an unspecified wafer orientation relative to the optical measurement system.

37. The instrument of claim 26 wherein the measurement station includes an optical absorber positioned to one side of the wafer support to provide a reference zero reflectance measure for bright background measurement.

38. The instrument of claim 26 wherein the measure of patterned features obtained by the data processor includes at least one dimension of lateral or vertical geometric structure of features on the wafer.

39. The instrument of claim 38 wherein the measure of patterned features include line width and profile of features of the wafer.

40. A wafer measurement method for cooperative use with a wafer process tool of the type having a wafer handler associated with a cassette of wafers, comprising:

within the wafer process tool after completion of any of one or more process steps carried out in processing stations of the process tool, receiving in an integrated measuring station of the process tool a wafer from a wafer handler associated with the process tool without first transferring wafers out of the process tool to another cassette or cassette loading station, and depositing the wafer at an unspecified orientation in the measurement station relative to a moveable optical measurement system;

moving an optical measurement system to a plurality of locations over the wafer ;

directing a beam of light normally onto the wafer surface as a light spot at each of said plurality of locations, the light spot characterized by a spot size that is larger at the wafer surface than a periodicity of pattern features on the wafer;

detecting light reflected from the wafer surface to obtain data for an optical characteristic of surface pattern features of the wafer at said plurality of locations; and

analyzing the optical characteristic data using a scattering model of possible periodic structures on a wafer to obtain a measure of critical dimensions of the surface pattern features on the wafer.

41. The method of claim 40 further defined by sequentially measuring reflectance data for a plurality wafers received from the wafer process tool.

42. A method of measuring a wafer within a wafer process tool, comprising:

transferring a wafer robotically from a process station of the process tool to a measurement station of the process tool;

positioning a measurement spot of an optical head of a measurement instrument within the measurement station over a first location of the wafer;

rotating the wafer and translating the optical head to position the measurement spot over a second location of the wafer;

repeating the wafer rotation and optical head translation to successively position the measurement spot over different locations of the wafer; and

measuring an optical characteristic of the wafer at each of the successive measurement locations.